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TITLE OF THE INVENTION

OPTICAL COATINGS FOR ULTRAVIOLET AND INFRARED REFLECTION

BACKGROUND OF THE INVENTION

(a) Field of the Invention

The present invention relates to coatings for ultraviolet and infrared reflection, and more particularly to multilayer structures which transmit visible light while effectively shading ultraviolet and infrared light with a plurality of layers having different refractive indices. More particularly, the present invention relates to window constructions on which the multilayer structure is formed.

(b) Description of the Related Art

Generally, ultraviolet light of a wavelength ranging between 10-400 nm may cause skin aging, eye fatigue, or cataracts in human bodies, and decolorization in articles, while infrared light of a wavelength ranging over 700 nm may generate heat causing the ambient temperature to rise. Human bodies and indoor articles may be damaged by ultraviolet light, specifically in vehicles or buildings in which windows take up much area. In summer time, the cost for air cooling is increased due to temperature rising because of infrared light.

In order to shade ultraviolet or infrared light, a color plastic sheet or a metal coating material may be applied to windows. Since the color plastic sheet or metal coating material shades visible light as well as ultraviolet and infrared light, however, it may cause full visibility or forward observation capability to be reduced, especially when driving. It may also cause indoor lighting to be insufficient.

A multilayer structure for shading infrared light has been developed as disclosed in Korean Patent Publication No. 1988-10930A to shade infrared light from sunlight, but the structure can merely reflect infrared light having a limited wavelength range of 900-1200 nm. The structure can shade neither infrared light having wavelengths over 1200 nm, nor ultraviolet and infrared light simultaneously.

SUMMARY OF THE INVENTION

In view of the prior art described above, it is an object of the present invention to provide a multilayer structure for shading both ultraviolet and infrared light effectively as well as for transmitting visible light, and a window construction in which the structure is formed.

It is another object of the present invention to provide a multilayer structure

with a plurality of materials having different refractive indices and different thicknesses for shading both ultraviolet and infrared light effectively, and a window construction in which the structure is formed.

It is still another object of the present invention to provide articles including safety glass for vehicles which shade both ultraviolet and infrared light.

To achieve these and other objects, as embodied and broadly described herein, a multilayer structure for shading ultraviolet and infrared light includes two or three layers of Ag; two or three layers of indium tin oxide (ITO); and dielectric oxide layers ranging from two layers to four layers. At least two Ag layers are formed to be in contact with the ITO layer as an upward or downward layer. Each dielectric oxide layer is made of a material which is selected from SiO_2, TiO_2, Al_2O_3, ZrO_2, Y_2O_3, and Ta_2O_5.

According to another aspect to the present invention, a window construction for ultraviolet and infrared shading includes a substrate of glass or plastic material;

two or three layers of Ag; two or three layers of indium tin oxide (ITO); and dielectric oxide layers ranging from two layers to four layers. At least two Ag layers are formed to be in contact with the ITO layer as an upward or downward layer.

The multilayer structure according to the present invention is formed by stacking a plurality of layers of coating materials having different refractive indices on a substrate of glass or a plastic such as acryl. Each layer of the structure can be deposited by a vapor deposition method such as physical vapor deposition (PVD) or chemical vapor deposition (CVD). The design of the structure employs multiple reflection, which occurs in each thin layer that is made of a coating material different from the others, in order to selectively reflect or transmit light having particular wavelength ranges. Each coating material is selected while taking its refractive index and optical properties into consideration, and the deposition thickness of each layer is determined while considering generation of multiple reflection for the desired wavelength ranges.

The present invention employs silver (Ag), indium tin oxide (ITO), and dielectric oxides as coating materials.

Silver (Ag) has good optical transmission properties for visible light and good reflection properties in infrared ranges. The thickness of the Ag layer preferably ranges from 5 nm to 15 nm.

Indium tin oxide (ITO) is an oxide of indium and tin, in which a ratio of In_2O_3

to SnO_2 ranges from 85:15 to 95:4. ITO has good optical transmission of more than 80% for visible light, independent of a deposited thickness.

The dielectric oxide is preferably selected from SiO_2, TiO_2, Al_2O_3, ZrO_2, Y_2O_3, and Ta_2O_5, and its thickness is determined according to each refractive index.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a graph of wavelength of incident light versus percent transmission of incident light through an optical coating according to a first embodiment of the present invention;

Fig. 2 is a graph of wavelength of incident light versus percent transmission of incident light through an optical coating according to a second embodiment of the present invention;

Fig. 3 is a graph of wavelength of incident light versus percent transmission of incident light through an optical coating according to a third embodiment of the present invention;

Fig. 4 is a graph of wavelength of incident light versus percent transmission of incident light through an optical coating according to a fourth embodiment of the present invention;

Fig. 5 is a graph of wavelength of incident light versus percent transmission of incident light through an optical coating according to a fifth embodiment of the present invention;

Fig. 6 is a graph of wavelength of incident light versus percent transmission of incident light through an optical coating according to a sixth embodiment of the present invention; and

Fig. 7 shows a cross-sectional view of a car window with the multilayer structure of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will hereinafter be described in detail with reference to the accompanying drawings.

<First Embodiment>

A multilayer structure for shading ultraviolet and infrared light according to the first embodiment of the present invention has seven layers, employing four coating materials such as Ag, ITO, SiO_2, and TiO_2.

The arrangement, refractive indices, and thicknesses of coating materials are listed in Table 1 below in order from a substrate.

TABLE 1

NO.	Material	Refractive Index (reference wavelength 510 nm)	Layer thickness(nm)
7	TiO_2	2.34867	28.81
6	Ag	0.051	14.38
5	ITO	2.058	84.63
4	Ag	0.051	8.07
3	TiO_2	2.34867	126.06
2	ITO	2.058	38.14
1	SiO_2	1.4618	162.79
Substrate	Glass	1.52077	

As shown in Table 1, the multilayer structure may employ four coating materials to form a seven-layer structure. Specifically, the fifth layer of ITO is embedded between the fourth layer of Ag and the sixth layer of Ag.

The shading of ultraviolet and infrared light in the multilayer structure is shown in Fig. 1, which illustrates a graph of transmission percent of incident light versus the wavelength of the incident light. The multilayer structure transmits about 1.77% of light having a wavelength of 200 nm and about 8% of light having a wavelength of 300 nm, to shade ultraviolet light, while it transmits more than 85% of visible light. Further, the transmittance of the structure is about 31% at a wavelength of 800 nm and is then reduced to less than 8% at a wavelength of 1000 nm, resulting in effective shading of the whole infrared range.

<Second Embodiment>

A multilayer structure for shading ultraviolet and infrared light according to the second embodiment of the present invention has seven layers, employing three coating materials such as Ag, ITO, and Y_2O_3.

The arrangement, refractive indices, and thicknesses of coating materials are listed in Table 2 below in order from a substrate.

TABLE 2

NO.	Material	Refractive Index (reference wavelength 510 nm)	Layer Thickness(nm)
7	Y_2O_3	1.79581	4.08
6	ITO	2.058	36.14
5	Ag	0.051	12.82
4	ITO	2.058	71.91
3	Ag	0.051	9.39
2	Y_2O_3	1.79581	85.56
1	Ag	0.051	5.79
Substrate	Glass	1.52077	

As shown in Table 2, the multilayer structure may employ three coating materials to form a seven-layer structure. Specifically, the third layer of Ag and fifth layer of Ag are alternatively formed with the fourth layer of ITO and the sixth layer of ITO.

The shading of ultraviolet and infrared light in the multilayer structure is shown in Fig. 2, which illustrates a graph of transmission percent of incident light versus the wavelength of the incident light. The multilayer structure transmits about 3.5% of light having a wavelength of 200 nm and about 9.5% of light having a wavelength of 300 nm, to shade ultraviolet light, while it transmits more than 85% of visible light. Further, the transmittance of the structure is about 32% at a wavelength of 800 nm and then is reduced to less than 4% at a wavelength of 1000 nm, resulting in effective shading of the whole infrared range.

<Third Embodiment>

A multilayer structure for shading ultraviolet and infrared light according to the third embodiment of the present invention has seven layers, employing three coating materials such as Ag, ITO, and ZrO_2.

The arrangement, refractive indices, and thicknesses of coating materials are listed in Table 3 below in order from a substrate.

TABLE 3

NO.	Material	Refractive Index (reference wavelength 510 nm)	Layer Thickness(nm)
7	ZrO_2	2.06576	9.58
6	ITO	2.058	29.57
5	Ag	0.051	13.07
4	ITO	2.058	76.34
3	Ag	0.051	10.05
2	ZrO_2	2.06576	63.84
1	Ag	0.051	5.6
Substrate	Glass	1.52077	

As shown in Table 3, the multilayer structure may employ three coating materials to form a seven-layer structure. Specifically, the third layer of Ag and fifth layer of Ag are alternatively formed with the fourth layer of ITO and the sixth layer of ITO.

The shading of ultraviolet and infrared light in the multilayer structure is shown in Fig. 3, which illustrates a graph of transmission percent of the incident light versus the wavelength of the incident light thereof. The multilayer structure transmits about 3.2% of light having a wavelength of 200 nm and about 9.7% of light having a wavelength of 300 nm, to shade ultraviolet light, while it transmits more than 85% of visible light. Further, the transmittance of the structure is about 32.5% at a wavelength of 800 nm, and is then reduced to less than 9% at a wavelength of 1000 nm, resulting in effective shading of the whole infrared range.

<Fourth Embodiment>

A multilayer structure for shading ultraviolet and infrared light according to the fourth embodiment of the present invention has eight layers, employing four coating materials such as Ag, ITO, SiO_2, and Ta_2O_5.

The arrangement, refractive indices, and thicknesses of coating materials are listed in Table 4 below in order from a substrate.

TABLE 4

NO.	Material	Refractive Index (reference wavelength 510 nm)	Layer Thickness(nm)

8	Ta_2O_5	2.14455	35
7	Ag	0.051	13.38
6	ITO	2.058	79.89
5	Ag	0.051	11.06
4	Ta_2O_5	2.14455	72.4
3	Ag	0.051	10.76
2	ITO	2.058	34.18
1	SiO_2	1.4618	103.67
Substrate	Glass	1.52077	

As shown in Table 4, the multilayer structure may employ four coating materials to form an eight-layer structure. Specifically, the third layer of Ag is formed on the second layer of ITO, and the sixth layer of ITO is embedded in the fifth layer of Ag and the seventh layer of Ag.

The shading of ultraviolet and infrared light in the multilayer structure is shown in Fig. 4, which illustrates a graph of transmission percent of the incident light versus the wavelength of the incident light thereof. The multilayer structure transmits about 0.08% of light having a wavelength of 200 nm and about 6.8% of light having a wavelength of 300 nm, to shade ultraviolet light, while it transmits more than 85% of visible light. Further, the transmittance of the structure is about 29% at a wavelength of 800 nm and is then reduced to less than 2% at a wavelength of 1000 nm, resulting in effective shading of the whole infrared range.

<Fifth Embodiment>

A multilayer structure for shading ultraviolet and infrared light according to the fifth embodiment of the present invention has nine layers, employing four coating materials such as Ag, ITO, SiO_2, and Al_2O_3.

The arrangement, refractive indices, and thicknesses of coating materials are listed in Table 5 below in order from a substrate.

TABLE 5

NO.	Material	Refractive Index (reference wavelength 510 nm)	Layer Thickness(nm)
9	SiO_2	1.4618	3.58

8	ITO	2.058	36.91
7	Al_2O_3	1.6726	5
6	Ag	0.051	15.28
5	ITO	2.058	78.88
4	Al_2O_3	1.6726	5
3	Ag	0.051	12.42
2	ITO	2.058	40.64
1	SiO_2	1.4618	78.7
Substrate	Glass	1.52077	

As shown in Table 5, the multilayer structure may employ four coating materials to a form nine-layer structure. Specifically, the third layer of Ag and the sixth layer of Ag are formed on the second layer of ITO and the fifth layer of ITO, respectively.

The shading of ultraviolet and infrared light in the multilayer structure is shown in Fig. 5, which illustrates a graph of transmission percent of incident light versus the wavelength of the incident light. The multilayer structure transmits about 5% of light having a wavelength of 300 nm to shade ultraviolet light, while it transmits more than 85% of visible light. Further, the transmittance of the structure is about 24% at a wavelength of 800 nm, and is then reduced to less than 4.2% at a wavelength of 1000 nm, resulting in effective shading of the whole infrared range.

<Sixth Embodiment>

A multilayer structure for shading ultraviolet and infrared light according to the sixth embodiment of the present invention has ten layers, employing four coating materials such as Ag, ITO, SiO_2, and Al_2O_3.

The arrangement, refractive indices, and thicknesses of coating materials are listed in Table 6 below in order from a substrate.

TABLE 6

NO.	Material	Refractive Index (reference wavelength 510 nm)	Layer Thickness(nm)
10	Al_2O_3	1.6726	16.21
9	ITO	2.058	12.57

8	Al_2O_3	1.6726	23.76
7	Ag	0.051	12.29
6	ITO	2.058	74.88
5	Ag	0.051	11.79
4	Al_2O_3	1.6726	111.82
3	Ag	0.051	10.65
2	ITO	2.058	40.77
1	SiO_2	1.4618	78.9
Substrate	Glass	1.52077	

As shown in Table 6, the multilayer structure may employ four coating materials to form a ten-layer structure. Specifically, the third layer of Ag is formed on the second layer of ITO; and the sixth layer of ITO is embedded in the fifth layer of Ag and the seventh layer of Ag.

The shading of ultraviolet and infrared light in the multilayer structure is shown in Fig. 6, which illustrates a graph of transmission percent of incident light versus the wavelength of the incident light. The multilayer structure transmits about 4.7% of light having a wavelength of 300 nm, to shade ultraviolet light, while it transmits more than 85% of visible light. Further, the transmittance of the structure is about 21% at a wavelength of 800 nm, and is then reduced less than 1.6% at a wavelength of 1000 nm, resulting in effective shading of the whole infrared range.

The present invention provides the multilayer structure which effectively reflects both infrared and ultraviolet light, while it transmits visible light. The multilayer structure may be employed in various applications such as window glass for vehicles, buildings, or exhibits in museums, in plasma display panels (PDPs), and so forth. The window glass with the multilayer structure may prevent the ambient temperature from rising, and it may protect human skin and avoid decolorization of articles.

Specifically, the multilayer structure may reduce more than 30% of the inside temperature in a vehicle under sunlight in summer time to save fuel. Further, it may even be applied to a front window of a vehicle on which a color plastic sheet may not legally be attached.

Referring to Fig. 7, a safety glass 100 for vehicles according to the present

invention is comprised of two transparent panes 10 of glass or a plastic material, having a plastic film 30 between them. The plastic film 30 is made of plasticized polyvinyl butyral (PVB), and if the glass breaks, the fragments will adhere to the plastic film.

The multilayer structure 20 according to the present invention is formed between one of the panes 10 and the plastic film 30 to effectively shade ultraviolet light and infrared light incident to the inside of the vehicle. Since the multilayer structure 20 is not exposed to the outside, it may be difficult to damage.

It will be apparent to those skilled in the art that various modifications and variations can be made to the present invention without departing from the spirit and scope of the invention.